Jan. 17, 1967 E. E. CONNER ET AL 3,299,383

CURRENT TRANSFORMER HAVING FLUID CARRY PASSAGES IN HIGH VOLTAGE CONDUCTOR

Filed Nov. 4, 1965

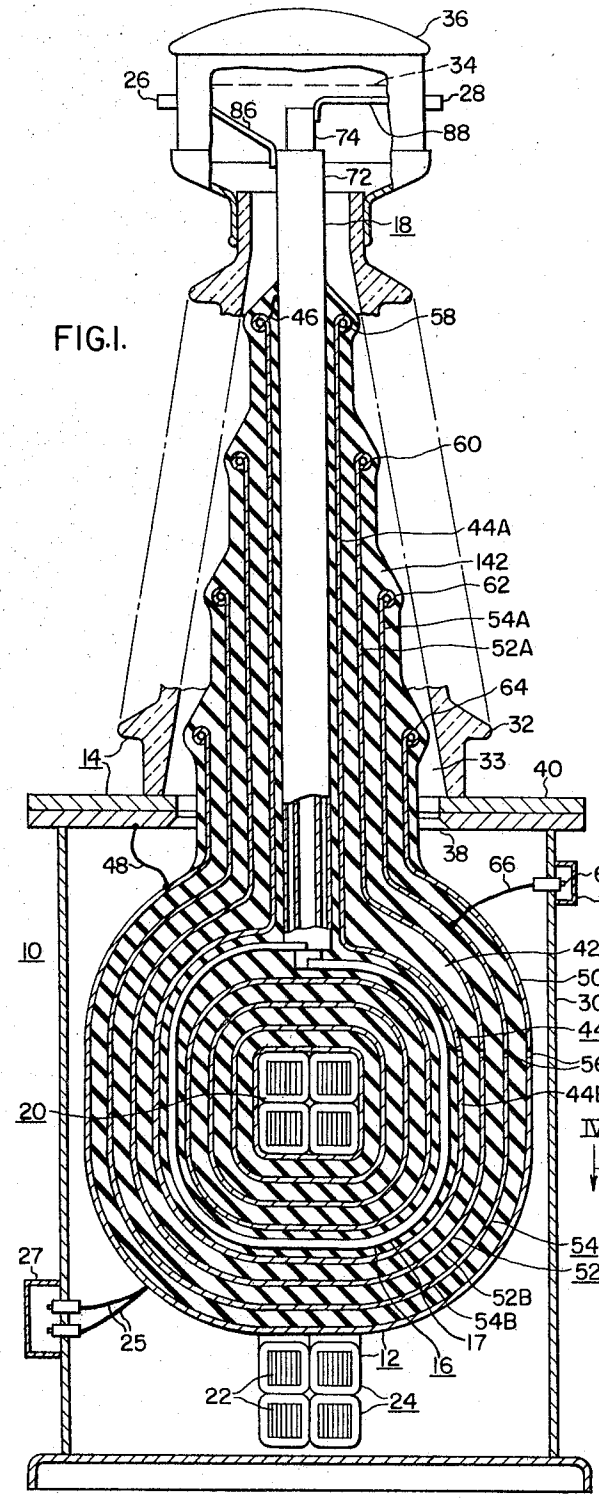


FIG.1.

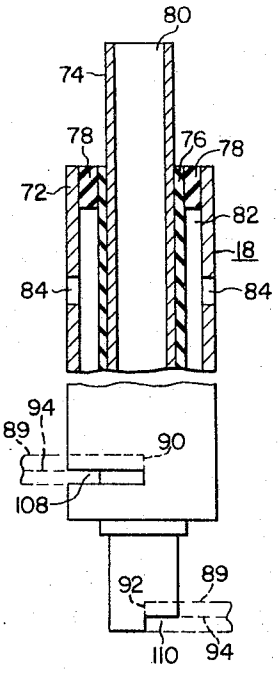


FIG.2.

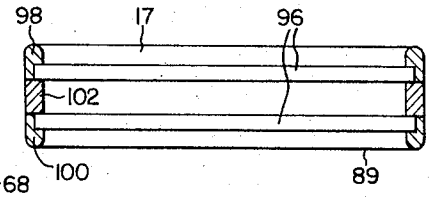


FIG.4.

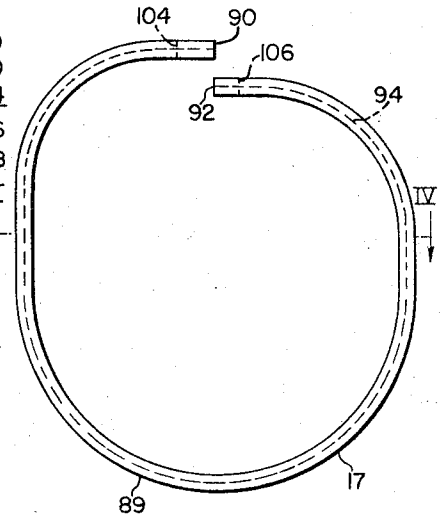


FIG.3.

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3,299,383

# CURRENT TRANSFORMER HAVING FLUID CARRY PASSAGES IN HIGH VOLTAGE CONDUCTOR

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8 Claims. (Cl. 336—60)

This invention relates in general to electrical inductive apparatus, such as transformers, and more particularly to winding and insulation structures for high voltage current transformers.

Solid insulation systems for instrument transformers, such as those which employ oil impregnated paper sheet or tape, continuously wound to provide a plurality of layers having a predetermined thickness, have significantly reduced the size and cost of instrument transformers compared to those which utilize the oil-pressboard barrier insulation systems. The solid insulation systems have been successfully applied to current transformers in the voltage range of 150 kv. BIL through 900 kv. BIL. In attempting to apply the solid insulation system to current transformers in the extra high voltage range, such as 1300–1800 kv. BIL, it became apparent that the conventional winding and solid insulation arrangements were not suitable, as removal of heat became a major problem. The heat problem arises at the higher BIL levels due to several factors. The higher voltage current transformers are coupled with higher current requirements, up to 3000 amperes; therefore, the losses are higher than in the lower rated current transformers, producing more heat which must be removed from the windings. The higher voltages also require that the porcelain bushing or weather housing be substantially increased in length, which increases the length of the high voltage coil leads, and increases the lead losses accordingly. The thickness of the solid insulation applied to the electrical leads and high voltage winding of current transformers in the extra high voltage range is also substantially increased over the lower voltage designs, reaching a point where substantially no heat can be removed through the solid insulation. All of these factors, plus the requirement that the hot spot temperature must be carefully controlled and held to a low value for thermal stability considerations, make the present solid insulation system arrangements impractical for current transformers in the extra high voltage class. Thus, it would be desirable to provide a new and improved winding and solid insulation arrangement for current transformers in the extra high voltage class, in which the advantage of solid insulation may be realized, and which will control and maintain the hot spot temperature at the required low value.

Accordingly, it is an object of the invention to provide a new and improved high voltage current transformer assembly.

A further object of the invention is to provide a new and improved winding and insulation arrangement for high voltage instrument transformers.

Another object of the invention is to provide a new and improved lead and winding arrangement for high voltage current transformers, which effectively dissipates the electrical losses and allows the successful use of solid insulation systems.

Briefly, the present invention accomplishes the above cited objects by providing a new electrical lead and winding arrangement for high voltage current transformers, which allows free thermal siphon flow of the transformer cooling fluid in thermal communication with the electrical leads and winding. The new lead and winding assembly allows substantially all of the losses or heat to be removed by the cooling fluid, and thus solid insulation may be utilized without regard to its heat insulating effect.



More specifically, the high voltage leads for the current transformer are formed of two concentrically disposed tubular electrically conductive members, spaced to provide flow paths for the transformer insulating and cooling fluid between the outer diameter of the inner lead and the inner diameter of the outer lead, and the opening formed by the inner diameter of the inner lead. The high voltage winding is formed of a single electrical conductor which has grooves or channels disposed therein which form flow paths for the cooling fluid when the solid insulation is applied to the winding. The high voltage winding is connected to the electrical leads such that the openings to the winding coolant flow paths on one end of the winding communicate with the coolant flow path between the two concentrically disposed leads, and the openings to the coolant flow paths on the other end of the winding communicate with the coolant flow path inside the inner lead. Thus, the transformer cooling fluid is free to flow in the winding under the influence of the thermal siphon effect, up through the electrical leads, with the rising heated fluid being replaced by cooler fliud flow in the opposite direction from the reservoir of cooled fluid disposed at the upper end of the current transformer assembly.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 is an elevational view, in section, of a current transformer constructed according to the teachings of the invention;

FIG. 2 is an elevational view, partially in section, illustrating in greater detail the electrical lead assembly of the current transformer shown in FIG. 1;

FIG. 3 is an elevational view illustrating, in greater detail, the high voltage winding assembly of the current transformer shown in FIG. 1; and

FIG. 4 is a cross sectional view of the high voltage winding assembly of FIG. 3, taken along the lines IV—IV.

Referring now to the drawings, and FIG. 1 in particular, there is illustrated an elevational view, in section, of a high voltage current transformer **10** constructed according to the teachings of the invention. Current transformer **10** includes a winding-core assembly **12**, disposed wihtin a suitable housing **14**. The winding-core assembly **12** comprises high voltage winding assembly **16**, low voltage winding assembly **20**, and magnetic core means **22**. The low voltage winding assembly **20** may include one or more separate windings, each disposed in inductive relation with a magnetic core member, with the number of winding and core members depending upon the requirements of the particular application the current transformer **10** is to be utilized with. For example, FIGURE 1 illustrates a low voltage winding assembly having four low voltage windings and four magnetic core members. Electrical leads **25** extend from low voltage winding assembly **20** to a suitable terminal box **27** disposed on the enclosure or housing **14**. High voltage winding assembly **16** and low voltage winding assembly **20** are disposed in inductive relation with a leg on magnetic core means **22**, and equalizer windings, such as windings **24**, may be disposed in inductive relation with the remaining legs of the magnetic core means **22**, in a manner well known in the art.

The high voltage winding assembly **16** includes high voltage winding section **17** and lead assembly **18**, with

the lead assembly 18 extending upwardly from the high voltage winding section 17 and electrically connected to terminals 26 and 28 through electrical conductors 86 and 88, respectively. Terminals 26 and 28 are adapted for connection to an alternating current power system whose current is to be measured or sensed.

Housing 14 includes a tank 30 for containing the high and low voltage winding assemblies 16 and 20, respectively, and a hollow cylindrical porcelain bushing or outdoor weather housing 32 having a central opening 33 that is tapered in cross section along its vertical axis, for enclosing the high voltage lead assembly 18. The tank 30 has an opening 38 disposed through its top or upper portion 40, and the bushing 32 is disposed in sealed engagement with the top portion 40, with its vertical axis substantially perpendicular thereto and the opening 33 in the bushing 32 being in registry or alignment with the opening 38 in the top 40 of the tank 30. The tank 30 and bushing 32 are filled with a suitable fluid dielectric for cooling and insulating the transformer 10, such as oil, to the level indicated at line 34. An expansion cap 36 is disposed at the top of bushing 32 to allow for expansion and contraction of the fluid dielectric as the thermal condition of the current transformer 10 changes during operation.

The low voltage winding assembly 20 is disposed inside the high voltage winding assembly 16. In order to insulate the high voltage winding section 17 from the low voltage winding assembly 20 and from the grounded portions of the transformer housing, such as the tank 30, solid insulation 42 is disposed to surround the high voltage section 17. The solid insulation 42 may be any suitable insulating material, such as crepe paper, in sheet or tape form, which is either taped, wrapped or folded around the high voltage winding section 17, and between the high voltage winding section 17 and low voltage winding assembly 20.

In order to electrically insulate the high voltage lead assembly 18 from the grounded portion of the transformer housing 14, such as the portion of the tank 30 which surrounds the opening 38, solid insulation 142 is disposed to substantially surround at least the major vertical portion of the lead assembly 18. The solid insulation 142 may be similar to the solid insulation 42 surrounding the high voltage winding section 17, and may be crepe paper in flexible sheet form which is taped, wrapped or folded about the lead assembly 18. The thickness of the solid insulation 142 is generally tapered from a maximum value at the lower portion of the lead assembly 18 to a minimum value near the upper portion of the lead assembly. The entire solid insulation structure may be oil impregnated using high vacuum techniques.

The absence of oil ducts in the solid insulation system substantially eliminates or reduces the possibility of voids or pockets in the solid insulation surrounding the high voltage section 17 and lead assembly 18, which would otherwise be filled with a dielectric fluid having a lower specific inductive capacity than the associated solid insulation. The presence of such voids or pockets in areas of high dielectric stress is particularly undesirable at higher operating potentials, and may eventually lead to an insulation failure or breakdown in the solid insulation surrounding the high voltage winding and leads.

In order to reduce the concentration of dielectric stress in the solid insulation 42 surrounding the high voltage winding section 17, particularly adjacent to the outer ends or corners of said high voltage winding, and in the solid insulation 142 surrounding the lead assembly 18, an inner shielding member 44 having upper and lower portions 44A and 44B, respectively, is disposed to substantially surround the high voltage winding section 17 and the major portion of lead assembly 18. The upper portion of the inner shield 44 may be formed by tightly winding a flexible conducting material having a layer of insulation secured thereto, such as crepe paper backed metallic foil, in the form of a sheet or tape substantially around the lead assembly 18 at a predetermined point in the build of the solid insulation 142. The upper and lower portions 44A and 44B, respectively, of the inner shielding member 44 are electrically connected to one another to form a continuous conducting path throughout the shielding member 44 which will limit the potential difference between the different portions thereof to a negligible value so that there is no interruption in the shielding effect between the upper and lower portions of the shielding member 44.

The upper end of the inner shielding member 44 is electrically connected to lead assembly 18 by electrical conductor 46, in order for the shielding member 44 to provide a substantially equipotential surface around the high voltage winding section 17 and high voltage lead assembly 18, which is at substantially the same potential as the high voltage winding 17, to thereby substantially eliminate any potential stress to which any fluid dielectric inside said lead assembly is subjected.

In order to reduce the concentration of dielectric stress in the solid insulation 142 which surrounds lead assembly 18 adjacent to the grounded portions of the tank 30 through which said lead assembly 18 passes, and to substantially eliminate any potential stress to which the fluid dielectric is subjected inside the tank 30 and in the lower portion of the central opening of the bushing 32, an outer shielding member 50 is disposed to substantially surround the high voltage winding section 17 and its associated solid insulation 42, as well as the lower portion of lead assembly 18 and the solid insulation 142 which is disposed around said lead assembly.

The outer shielding member 50 is formed by winding around and through the central opening of the high voltage winding section 17 a flexible electrically conductive material having a layer of insulation secured thereto for mechanical purposes, after the solid insulation 42 has been assembled around the high voltage winding section 17; and, by winding the same type of flexible electrically conductive sheet material snugly and tightly around the outer surface of solid insulation 142 after the insulation has been assembled around the lead assembly 18. The outer shield member 50 may be formed of materials such as aluminum foil backed crepe paper or carbon backed crepe paper. Carbon backed crepe paper has advantages in some instances over metal backed crepe paper, in that wrinkles and sharp edges are not as detrimental when using carbon backed paper as opposed to metallic type shields. Also, the higher resistance of carbon has a potential grading effect because the displacement current due to stress concentration causes a voltage drop along the semiconducting layer. This phenomenon is well known and utilized in condenser bushings and windings of high voltage generators. It is also known that due to so called "surface activity," an insulation with a semiconducting electrode, such as carbon, in the highest stressed boundary has higher dielectric strength than a system with metallic electrodes only.

The outer shielding member 50 forms a continuous electrically conductive surface or electrode having a cylindrical configuration around the high voltage winding section 17 and a generally hollow-cylindrical shape around the lower portion of lead assembly 18. The outer shielding member 50 is maintained at ground or zero potential by electrically connecting said shielding member by a flexible conducting lead 48 as indicated in FIG. 1, to the tank 30, or any other grounded portion of the transformer 10. The outer shielding member 50 is disposed in substantially concentric relation with the inner shielding member 44, and similar to the inner shielding member 44, the outer shielding member 50 forms a continuous, substantially equipotential surface around the outer surface of the solid insulation 42 and the outer surface of the lower portion of the solid insulation 142. The flexible shielding material from which

the outer shielding member **50** is formed permits said shielding member to closely follow the contour or outer surface of the solid insulation and prevents the occurrence of voids or pockets which would otherwise be filled with the associated fluid dielectric and which would be subject to possible insulation failure or breakdown.

In order to reduce the maximum potential gradient in the solid insulation **42** adjacent the outer corners of high voltage winding section **17**, and produce a favorable voltage distribution longitudinally along the bushing **32**, as described in detail in U.S. Patent 3,173,114, which is assigned to the same assignee as the present application, intermediate shielding members **52** and **54** having upper and lower portions **52A** and **52B**, and **54A** and **54B**, respectively, are disposed to substantially surround the high voltage winding section **17** and the lower portion of the lead assembly **18**. The upper and lower portions of intermediate shielding members **52** and **54** may be formed in a manner similar to the outer shielding member **50** as previously described, by winding a flexible conducting or semiconducting material having a layer of insulation secured thereto, such as crepe paper with metallic foil or carbon attached to it, in the form of a tape or sheet, around the high voltage winding section **17** at predetermined spaced intervals after predetermined builds of solid insulation have been assembled around the high voltage winding section **17** and around the lower portion of the lead assembly **18**. Only two intermediate shielding members, **52** and **54**, are shown in FIG. 1 for simplicity, but it is to be understood that for extra high voltage ratings, it may be desirable to have a larger plurality of intermediate shielding members.

When carbon backed crepe paper is used, instead of metallic foil backed crepe paper, its higher resistivity makes it possible to allow the shield to form a complete circuit around the core leg that carries the high and low voltage windings **16** and **20**, respectively. When metal backed crepe paper is used, it is necessary to include a gap in the shielding to prevent a short circuited turn around the magnetic core. For example, shielding members **44**, **50**, **52** and **54**, each have a gap shown therein, such as gap **56**.

Since the shielding members, such as members **44**, **52**, **54** and **50** require considerable time to properly tape into position with the solid insulation, and since the time required to remove moisture from the solid insulation during subsequent processing is increased with each shielding member added, it is important to use the minimum number of shielding members necessary to accomplish the desired results. Therefore, it is essential that the edges of the shielding members be terminated in a manner which prevents the formation of high localized stresses in the adjacent solid insulation. Without suitable terminating means for the edges of the shielding members, the number of shielding members would be determined by the number required to reduce the electrical stress between shielding members to the relatively low value necessary to reduce the voltage gradient at the edges of the shielding members to magnitudes less than the dielectric strength of the solid insulation.

An excellent structure for terminating the shielding members is to dispose an electrically conductive ring of circular cross-section at the edge of the shielding members, and electrically connected thereto. The radius of the cross section should exceed that minimum radius required to reduce the voltage gradient at the shield edge to below breakdown strength of the solid insulation. For example as shown in FIG. 1 shielding members **44**, **52**, **54** and **50** may be terminated with electrically conductive stress rings **50**, **60**, **62** and **64**.

The cross section of rings **58**, **60**, **62** and **64**, instead of being circular, may be substantially circular with a taper to provide an increased radius between the ring and its interface with the solid insulation, to even further reduce the maximum voltage gradient.



If a stress ring is used, such as rings **58**, **60**, **62** and **64**, a guard collar of solid insulation (not shown) may be built up around the ring to provide a square surface at its upper edge and prevent a void or space from being created when the next layer of solid insulation is applied.

Suitable terminating means for the shielding means may also be formed by building up a suitable radius of solid insulation adjacent the termination of the shielding member, and pulling the edge of the shielding member over the radius.

The upper and lower portions of each intermediate shielding member are electrically connected to one another or formed from the same flexible conducting material to provide a continuous equipotential surface around the high voltage winding **17** and the lower portion of the lead assembly **18**. Similar to the outer shielding member **50**, the intermediate shielding members **52** and **54** form generally cylindrical electrode surfaces around the high voltage winding section **17** and also a generally cylindrical electrode surface around the lower portion of the lead assembly **18**, in substantially concentric or parallel relation with the inner shielding member **44** and the outer shielding member **50**. The intermediate shielding members **52** and **54** reduce the critical voltage gradients in the solid insulation **42**, making possible a marked reduction in the amount of major insulation required and improving the corona characteristics of the transformer **10**. A further advantage of the intermediate shielding members is a more favorable voltage distribution longitudinally along the bushing **32**. This more linear voltage distribution along the bushing **32** also contributes to a reduction in the amount of fluid dielectric and major solid insulation required.

It is to be understood that the outer shielding member **50** may be omitted in certain applications, with the metallic casing **30**, which is normally at ground potential, functioning as an effective outer shield.

If it is desired to obtain an indication of the potential of the alternating current power system to which current transformer **10** is connected, an electrical lead may be connected to one of the intermediate shields, such as lead **66** connected to intermediate shield **54**, and brought out through the wall of tank **30** through bushing member **68**, to a suitable terminal box **70**.

The solid insulation structure of high voltage winding **16**, hereinbefore described, makes maximum usage of the dielectric strength of the solid insulation, reducing the size and weight of the transformer for a particular BIL rating to a minimum. However, when applied to extra high voltage designs, the thickness of the solid insulation required reaches a point where practically no heat can be dissipated through the solid insulation. Thus, it is imperative, if solid insulation with its advantages over the prior art pressboard-barrier design is to be used, that some highly efficient means be utilized to remove the heat from the high voltage winding section **17** and high voltage lead assembly **18**.

The teachings of this invention disclose a new and improved high voltage lead and winding assembly that not only efficiently removes the heat generated by the high voltage winding and lead assembly, but does so with an uncomplicated rugged structure that facilitates manufacture and assembly.

As shown generally in FIG. 1, and in greater detail in FIG. 2, the high voltage lead assembly **18** includes two electrically conductive tubular members **72** and **74**, which are connected to the ends of the high voltage winding section **17** and which extend vertically upward therefrom through opening **38** in the tank **30**, through opening **33** in bushing member **32**, and into the expansion cap **36**. The diameter and wall thickness of the tubular members **72** and **74** are selected to allow tubular member **72** to be telescoped over tubular member **74**, and

axially aligned to provide a predetermined space between the outer diameter of tubular member **74** and the inner diameter of tubular member **72**. Thus, the lead assembly **18** comprises inner and outer spaced tubular or hollow conductors **74** and **72**, respectively, disposed on a common center line or vertical axis. The inner conductor **74** has a length which exceeds the length of the outer conductor, to allow it to extend past both ends of the outer conductor, as shown in FIGS. 1 and 2.

The inner and outer axially aligned tubular conductors **74** and **72**, respectively, may be assembled in any suitable manner. An arrangement which has been found to be very satisfactory is shown in FIG. 2. In this instance, the inner conductor **74**, which may be fabricated from copper, aluminum or any other suitable electrical conductor, has a close fitting tubular insulating member **76** disposed thereon which is substantially the same length as the outer tubular conductor **72**, and is disposed to allow the ends of inner conductor **74** to extend outwardly from both ends of the tubular insulating member **76**. Tubular insulating member **76** may be formed of one of the laminated plastic materials, pressboard, or it may be in the form of an insulating tape which is wound thereon to a predetermined thickness.

After tubular insulating member **76** is disposed in the proper location over the outside diameter of inner tubular lead conductor **74**, the outer tubular lead conductor **72** is disposed coaxially over the inner conductor **74** until the desired axial relationship of the two conductors is established. Discrete insulating spacer members **78** are then disposed in spaced relation about the outside diameter of tubular insulating member **76**, and between said tubular insulating member and the inner diameter of outer lead conductor **72**. The spacer members **78** are disposed at the upper end as shown in FIG. 2, and also at the lower end of the lead assembly **18**. Thus, a lead assembly **18** is formed which has two separate flow paths for insulating fluid, the first being the space **80** formed by the inside diameter of the inner lead conductor **74**, and the second being the space **84** formed between the outside diameter of inner lead conductor **74** and the inside diameter of outer lead conductor **72**.

Outer conductor **72** may have spaced openings **84** disposed near its upper end, which allows heated fluid dielectric to exit the lead assembly near the bottom of the expansion cap **36**, to allow it to flow over as much of the surface of the expansion cap **36** as possible, to aid in cooling the fluid dielectric.

Electrical conductor **86** connects the outer tubular lead conductor **72** with terminal **26**, and electrical conductor **88** connects the upper extension of inner lead conductor **74** with terminal **28**. The connections of the inner and outer lead conductors, **74** and **72**, to the high voltage winding section will be described hereinafter.

The high voltage winding section **17**, shown generally in FIG. 1 and in greater detail in FIGS. 3 and 4, is formed of a single electrically conductive member, and is shaped into one or more turns having channels or grooves formed therein for purposes of providing a coolant flow path when solid insulation is disposed thereon.

More specifically, FIG. 3 illustrates, in this instance, a single turn winding section **17**, showing how an electrically conductive member **89** is shaped into substantially a circular or round cornered square configuration, with the ends **90** and **92** of the conductive member **89** being offset from one another vertically to facilitate connecting the conductor ends to lead assembly **18**. As shown by dotted line **94** in FIG. 3, and more clearly in FIG. 4, which is a cross sectional view of the winding section **17** of FIG. 3, taken along the lines IV—IV, the conductive member **89** has a plurality of channels or grooves **96** disposed about the inside diameter of the winding section **17**. In this instance, the conductive member **89** has two channels, but any desired number may be utilized. Two channels **96** are convenient, as an excellent method of forming winding section **17** comprises milling a channel in an electrically conductive bar or strap which is substantially rectangular in shape, and which has four rounded corners. The rounded corners are for the purpose of reducing electrical stress concentration. The electrically conductive bar is then cut into two pieces, with the cut being perpendicular to the bottom of the channel disposed therein and midway across the width of the channel. The two pieces of the bar are then brazed to opposite sides of a third rectangular bar, thus forming an integral conductive member in which two channels are inherently formed. The third bar is selected to provide the conductive mass necessary to insure that the completed integral conductor assembly will adequately carry the current requirements of the transformer **10**. Thus, in FIG. 4, members **98** and **100** may have been formed of a single bar, which had been milled to provide a channel therein, and cut into two pieces **98** and **100**. Then, pieces **98** and **100** are suitably attached, such as by brazing, to bar **102**, which inherently forms the two channels **96**. After the integral conductive member **89** is completed, it may then be bent to the shape of winding section **17** shown in FIGS. 1 and 3 and the disposition of the solid insulation about the winding assembly closes the channels and forms closed cooling paths for the fluid dielectric. While this method of forming winding section **17** has been found to be very suitable, it will be understood that other methods and arrangements may also be used. It is only important to form a rugged structure having the necessary quantity and cross section of electrical conductor, which has one or more channels or grooves disposed therein for purposes of forming flow paths for the fluid dielectric.

After the high voltage winding section **17** has been formed, it is ready to be secured to the lead assembly **18**. In addition to electrically connecting the winding section **17** to the lead assembly **18**, it is also necessary to establish a connection between the flow paths **80** and **82** of the lead assembly **18** and the channels **96** of the winding section **17**. A complete uninterrupted flow path for the dielectric fluid must be established from the flow path **82** between the tubular leads or lead conductors **72** and **74**, through the grooves or channels **96** in the winding section **17**, and through the space **80** in the inside diameter of lead conductor **74**. This is accomplished by cutting the end **90** of winding conductor **89** into a semicircle, which has the same diameter as the outside diameter of lead conductor **72**, and by cutting the end **92** of winding conductor **89** into a semicircle which has substantially the same diameter as the outside diameter of lead conductor **74**. These semicircular cuts on ends **90** and **92** of winding conductor **89** are represented by dotted lines **104** and **106**, respectively, in FIG. 3. In actual practice, it may facilitate the cutting of the ends **90** and **92** to construct the conductor **89** longer than required, to allow complete circles to be cut of the proper diameter, near each end of the conductor **89**. Then, the conductor may have each end cut to length at substantially the midpoint of each circular cut.

In order to receive end **90** of winding section **17** and provide communication between the channels **96** of winding section **17** and the coolant path **82** in lead assembly **18**, the outer lead conductor **72** has a slot **108** cut therein a predetermined distance from its lower end, as shown in the figures, or at the end of the conductor, which slot is substantially perpendicular to the vertical axis of the lead conductor, and which extends substantially half way through the diameter of the conductor. The width of the slot, in the axial direction of the conductor is substantially the same as the depth of the channels **96** in the winding section **17**. The end **90** of winding conductor **89** is disposed with its semicircular cut in close engagement with the outside diameter of outer lead conductor **72**, with the channels **96** in communication with the slot

108, and the conductor 89 is then secured to lead assembly 72 in this position by any suitable means, such as brazing.

In order to receive end 92 of winding section 17 and provide communication between the channels 96 of winding section 17 and the coolant path 80 in the inside diameter of inner lead conductor 74, the inner lead conductor 74 has a slot 110 cut therein, which may be at its lower end, as shown, or a predetermined distance therefrom, and which is substantially perpendicular to the vertical axis of the conductor, extending substantially half way across the diameter of the conductor. The width of the slot, in the axial direction of the conductor, is substantially the same as the depth of the channels 96 in the winding section 17. The end 92 of winding conductor 89 is disposed with its semicircular cut in close engagement with the outside diameter of inner lead conductor 74, with the channels 96 in communication with the slot 110, and the conductor 89 is then secured to lead conductor 74 in this position by any suitable means, such as brazing.

Thus, the high voltage winding and lead assembly 16 is partially completed. The disposition of the solid insulation 42 and 142, along with the shielding members hereinbefore described, completes the high voltage winding and lead assembly. The disposition of the solid insulation 42 about the winding conductor 89 completely encloses the channels 96, and the solid insulation 42 also closes the openings to flow paths 80 and 82 at the lower end of lead assembly 18, except for channels 96 in communication with the flow paths 80 and 82 through the slots in the tubular lead conductors. When the high voltage winding and lead assembly 16 is completed, the low voltage winding assembly 20 and the magnetic core means are disposed in the central opening of the high voltage winding assembly, the complete assembly is disposed within tank 30, the bushing 32 and expansion cap 36 are placed in their proper positions, and the complete housing filled with a fluid dielectric to the level 34, a thermal siphon flow path for the dielectric fluid is established in direct communication with the heat producing electrical leads 72 and 74 and with the heat producing winding section 17. This flow path starts at the expansion cap, and includes space 80 in the inside diameter of inner lead conductor 74, the channels 96 in winding section 17, and the space 82 between the inner and outer lead conductors 72 and 74. Fluid flow is accomplished due to the thermal siphon effect by the counter flow method, wherein heated fluid rises up through the spaces 80 and 82, exiting through openings 84, the openings between spacer members 78, and the opening at the upper end of inner conductor 74, and cooler fluid flows down through the spaces 80 and 82 simultaneously.

It should be noted that winding conductor 89 was formed such that the channels 96 appear on the inside diameter of the high voltage winding section 17. The winding conductor 89 may also be formed such that the channels 96 appear on the outside diameter of high voltage winding section 17. This latter arrangement, however, is not as desirable. When the channels are disposed on the inside diameter of the winding conductor 89, the winding conductor 89 is electrically connected to the lead conductors nearer to the electrical connection at the opposite ends of the leads than the slots 108 and 110. Thus, the slots 108 and 110 do not reduce the cross sectional area of the current path through the leads. If the channels are disposed on the outside diameter of winding conductor 89, the slots will then be disposed between the electrical connection to the upper ends of the lead conductors 72 and 74 and the electrical connections of the lead conductors 72 and 74 to the winding conductor 89. Thus, the cross sectional area of the lead conductor 72 and 74 is reduced, which causes current crowding and possible overheating of the conductor in the area adjacent to the lower electrical connections to the lead conductors.



In summary, there has been disclosed a new and improved instrument transformer arrangement which successfully extends the solid insulation systems of the prior art into the extra high voltage range, such as 1300–1800 kv. BIL. The disclosed arrangement provides a rugged structure that facilitates manufacture and assembly, provides efficient cooling of the high voltage winding section, without requiring any auxiliary cooling through the solid insulation, and efficiently cools the long high voltage lead assembly necessitated by the long bushing required by the extra high voltage range.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

We claim as our invention:

1. A high voltage current transformer comprising a high voltage winding section, a high voltage lead assembly connected to said high voltage winding section, a low voltage winding section, a magnetic core, said high and low voltage winding sections being disposed in inductive relation with said magnetic core to form a winding-core assembly, a housing comprising a tank and bushing assembly, said winding-core assembly being disposed within said housing, dielectric fluid means disposed within said housing, said high voltage lead assembly including inner and outer concentrically disposed tubular electrically conductive members, said inner tubular electrically conductive member extending past the outer tubular electrically conductive member, at least at the ends which are connected to said high voltage winding section, the inside diameter of the outer tubular conductive member exceeding the outside diameter of the inner tubular conductive member to provide a first space for said dielectric fluid means, the inside diameter of said inner tubular conductive member providing a second space for said dielectric fluid means, said high voltage winding section having first and second ends and at least one opening therein which extends between its ends, the first end of said high voltage winding section being electrically connected to the outer tubular conductive member, with the at least one opening in said high voltage winding section being in communication with the first space for said dielectric fluid, the second end of said high voltage winding section being electrically connected to the inner tubular conductive member, with the at least one opening in said high voltage winding section being in communication with the second space for said dielectric fluid, said transformer being cooled by circulation of said dielectric fluid through the at least one opening in said high voltage winding section and through the first and second spaces for said dielectric fluid in said high voltage lead assembly.

2. The high voltage current transformer of claim 1 wherein said high voltage winding section is formed of a single electrically conductive member having cooling channels formed therein.

3. The high voltage current transformer of claim 1 wherein said high voltage winding section is formed of a single electrically conductive member having cooling channels formed therein on the inside diameter of the winding section.

4. The high voltage current transformer of claim 1 wherein the inner and outer tubular electrical conductive members contain slots at the junction of the high voltage winding section to provide a continuous path from the at least one opening in the high voltage winding section through the slots to the first and second spaces for said dielectric fluid in the high voltage lead assembly.

5. The high voltage current transformer of claim 1 wherein said high voltage winding section and at least a portion of the high voltage lead assembly are surrounded by solid insulation.

6. The high voltage current transformer of claim 5 wherein said solid insulation forms at least one side of the at least one opening in said high voltage winding section.

7. The high voltage current transformer of claim 1 wherein said high voltage winding section and at least a portion of the high voltage lead assembly is surrounded by solid insulation, and said solid insulation has a plurality of spaced shielding members disposed therein.

8. The high voltage current transformer of claim 1 wherein said high voltage winding section has a single



turn and the first and second ends of said high voltage winding section have semicircular cuts adapted for connection to the outer diameters of the inner and outer tubular electrically conductive members.

No references cited.

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